In [1]:

```
# Analisis Anova multifactorial

# 1. Carga inicial de datos.

if(!require(psych)){install.packages("psych")}
if(!require(FSA)){install.packages("FSA")}
if(!require(ggplot2)){install.packages("ggplot2")}
if(!require(car)){install.packages("car")}
if(!require(multcompView)){install.packages("multcompView")}
if(!require(lsmeans)){install.packages("lsmeans")}
if(!require(rcompanion)){install.packages("rcompanion")}


ln <- ("Algoritmo       Entrenamiento       Rendimiento
'Algoritmo A'        MT500           12000
'Algoritmo A'        MT500           14005
'Algoritmo A'        MT500           13508
'Algoritmo A'        MT500            9503
'Algoritmo A'        MT500           14004
'Algoritmo A'        MT1000           11502
'Algoritmo A'        MT1000           13006
'Algoritmo A'        MT1000           13252
'Algoritmo A'        MT1000           14253
'Algoritmo A'        MT1000           15003
'Algoritmo A'        MT5000          12504
'Algoritmo A'        MT5000          11504
'Algoritmo A'        MT5000           9500
'Algoritmo A'        MT5000          11506
'Algoritmo A'        MT5000          16000
'Algoritmo A'        MT50000          13008
'Algoritmo A'        MT50000          10506
'Algoritmo A'        MT50000          13005
'Algoritmo A'        MT50000          17002
'Algoritmo A'        MT50000          13008
'Algoritmo B'        MT500            11005
'Algoritmo B'        MT500            12007
'Algoritmo B'        MT500            12509
'Algoritmo B'        MT500            10504
'Algoritmo B'        MT500            12002
'Algoritmo B'        MT1000           12504
'Algoritmo B'        MT1000           13501
'Algoritmo B'        MT1000           13501
'Algoritmo B'        MT1000           13252
'Algoritmo B'        MT1000           15256
'Algoritmo B'        MT5000           12253
'Algoritmo B'        MT5000           11255
'Algoritmo B'        MT5000           10006
'Algoritmo B'        MT5000           11252
'Algoritmo B'        MT5000           14004
'Algoritmo B'        MT50000          12007
'Algoritmo B'        MT50000          11505
'Algoritmo B'        MT50000          14009
'Algoritmo B'        MT50000          15000
'Algoritmo B'        MT50000          12009
'Algoritmo C'        MT500             9000
'Algoritmo C'        MT500            11003
'Algoritmo C'        MT500            11505
'Algoritmo C'        MT500             9509
'Algoritmo C'        MT500            11003
'Algoritmo C'        MT1000           11508
'Algoritmo C'        MT1000           12508
'Algoritmo C'        MT1000           12506
'Algoritmo C'        MT1000           12254
'Algoritmo C'        MT1000           13253
'Algoritmo C'        MT5000           11255
'Algoritmo C'        MT5000           10257
'Algoritmo C'        MT5000            9500
'Algoritmo C'        MT5000            9255
'Algoritmo C'        MT5000           12009
'Algoritmo C'        MT50000          11000
'Algoritmo C'        MT50000           9509
'Algoritmo C'        MT50000          13009
'Algoritmo C'        MT50000          14005
'Algoritmo C'        MT50000          11001
")
```

```
# Se introduce la tabla.
Data <- read.table(textConnection(ln), header = TRUE)

# Se ordenan los datos según los ingresamos. (Evitar orden alfabético por R).
Data$Entrenamiento <- factor(Data$Entrenamiento, levels=unique(Data$Entrenamiento))

# 2. Verificación de la lectura de datos

library(psych)
headTail(Data)
str(Data)
summary(Data)
rm(ln)


# 3. Gráfico simple de interacción.

interaction.plot(x.factor = Data$Entrenamiento,
 trace.factor = Data$Algoritmo,
 response = Data$Rendimiento,
 fun = mean,
 type = "b",
 col = c("black", "red", "green"),
 pch = c(19,17,15),
 fixed = TRUE,
 leg.bty = "o")

# 4. Modelo lineal y ANOVA

model <- lm(Rendimiento ~ Entrenamiento + Algoritmo + Entrenamiento : Algoritmo, data = Data)

library(car)
Anova(model, type = "II")

# 5. Evaluación de supuestos

# Normalidad
x <- residuals(model)
library(rcompanion)
plotNormalHistogram(x)

# Disperción de los residuos
plot(fitted(model), residuals(model))

# Graficos del modelo lineal
plot(model)

# 6. Análisis post-hoc

library(lsmeans)
marginal <- lsmeans(model, pairwise ~ Algoritmo, adjust = "tukey")
marginal

# Funcion cld
library(multcomp)
CLD <- cld(marginal, alpha=0.05, Letters= letters, adjust="tukey")
CLD

# Análisis post-hoc entrenamiento
marginal <- lsmeans(model, pairwise ~ Entrenamiento, adjust = "tukey")
marginal

# Funcion cld
library(multcomp)
CLD <- cld(marginal, alpha=0.05, Letters= letters, adjust="tukey")
CLD


# 7. Gráfico final
library(FSA)

Sum <- Summarize(Rendimiento ~ Entrenamiento + Algoritmo, data = Data, digits = 3)
Sum$se <- Sum$sd / sqrt(Sum$n)
Sum$se <- signif(Sum$se, digits = 3)
Sum
```

```r
Sum$Entrenamiento <- factor(Sum$Entrenamiento,
 levels = unique(Sum$Entrenamiento))

# 8. Boxplot error estándar

library(FSA)
library(ggplot2)
pd <- position_dodge(.2)
ggplot(Sum, aes(x=Entrenamiento,
 y = mean,
 color = Algoritmo)) +
 geom_errorbar(aes(ymin=mean-se,
 ymax=mean + se),
 width=.2, size=0.7, position=pd) +
 geom_point(shape=15, size=4, position = pd) +
 theme_bw() +
 theme(axis.title = element_text(face="bold")) +
 scale_colour_manual(values = c("black", "red", "green")) +
 ylab("Rendimiento")
```

```
Loading required package: psych

Loading required package: FSA

## FSA v0.9.4. See citation('FSA') if used in publication.
## Run fishR() for related website and fishR('IFAR') for related book.


Attaching package: 'FSA'


The following object is masked from 'package:psych':

    headtail


Loading required package: ggplot2


Attaching package: 'ggplot2'


The following objects are masked from 'package:psych':

    %+%, alpha


Loading required package: car

Loading required package: carData

Registered S3 methods overwritten by 'car':
  method       from
  hist.boot    FSA
  confint.boot FSA


Attaching package: 'car'


The following object is masked from 'package:FSA':

    bootCase


The following object is masked from 'package:psych':

    logit


Loading required package: multcompView

Loading required package: lsmeans

Loading required package: emmeans

The 'lsmeans' package is now basically a front end for 'emmeans'.
Users are encouraged to switch the rest of the way.
See help('transition') for more information, including how to
convert old 'lsmeans' objects and scripts to work with 'emmeans'.

Loading required package: rcompanion


Attaching package: 'rcompanion'


The following object is masked from 'package:psych':

    phi
```

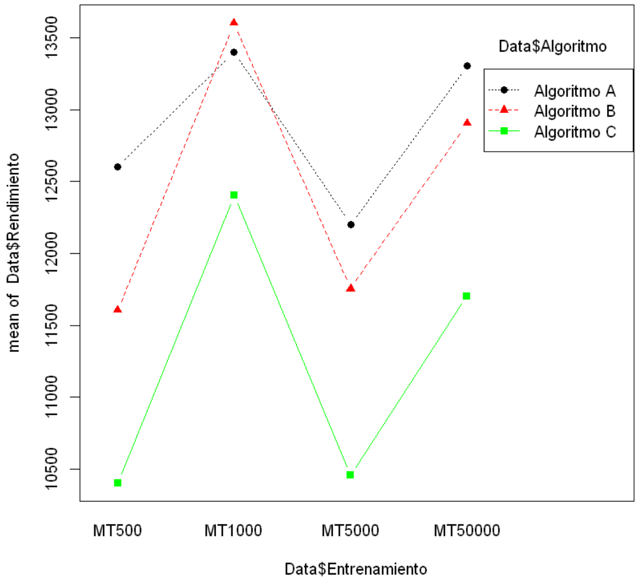
A data.frame: 9 × 3

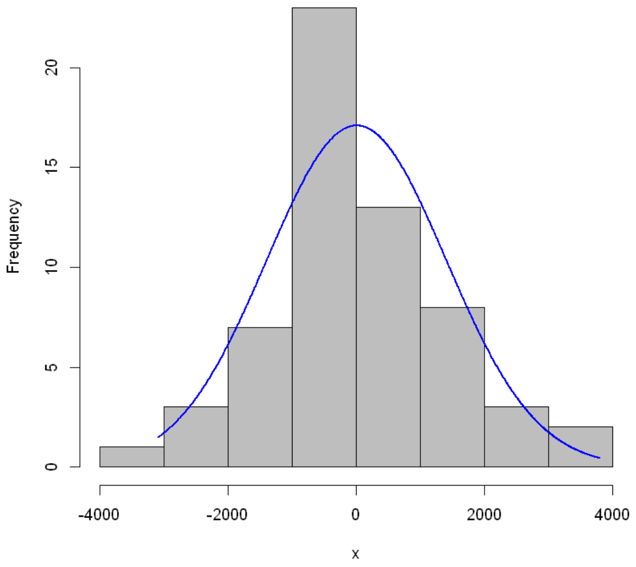
	Algoritmo	Entrenamiento	Rendimiento
	<chr>	<fct>	<chr>
1	Algoritmo A	MT500	12000
2	Algoritmo A	MT500	14005
3	Algoritmo A	MT500	13508
4	Algoritmo A	MT500	9503
...	NA	NA	...
57	Algoritmo C	MT50000	9509
58	Algoritmo C	MT50000	13009
59	Algoritmo C	MT50000	14005
60	Algoritmo C	MT50000	11001

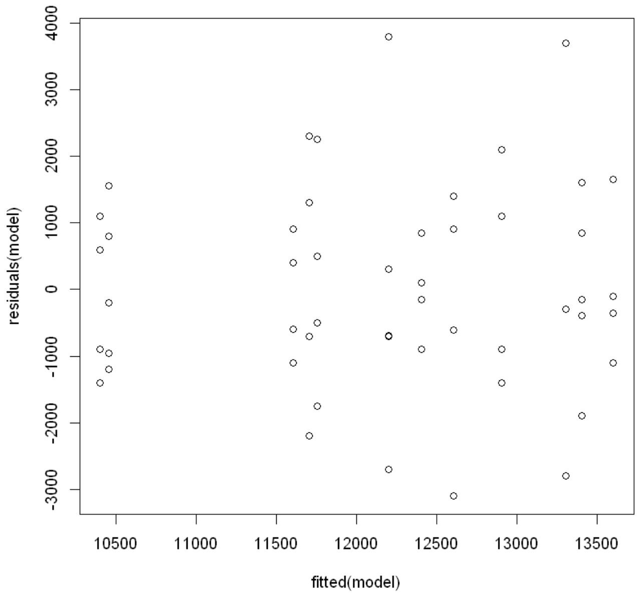
```
'data.frame':	60 obs. of  3 variables:
 $ Algoritmo    : chr  "Algoritmo A" "Algoritmo A" "Algoritmo A" "Algoritmo A" ...
 $ Entrenamiento: Factor w/ 4 levels "MT500","MT1000",..: 1 1 1 1 1 2 2 2 2 2 ...
 $ Rendimiento  : int  12000 14005 13508 9503 14004 11502 13006 13252 14253 15003 ...
  Algoritmo          Entrenamiento  Rendimiento  
 Length:60          MT500  :15     Min.   : 9000  
 Class :character   MT1000 :15     1st Qu.:11004  
 Mode  :character   MT5000 :15     Median :12009  
                    MT50000:15     Mean   :12196  
                                   3rd Qu.:13252  
                                   Max.   :17002  
```

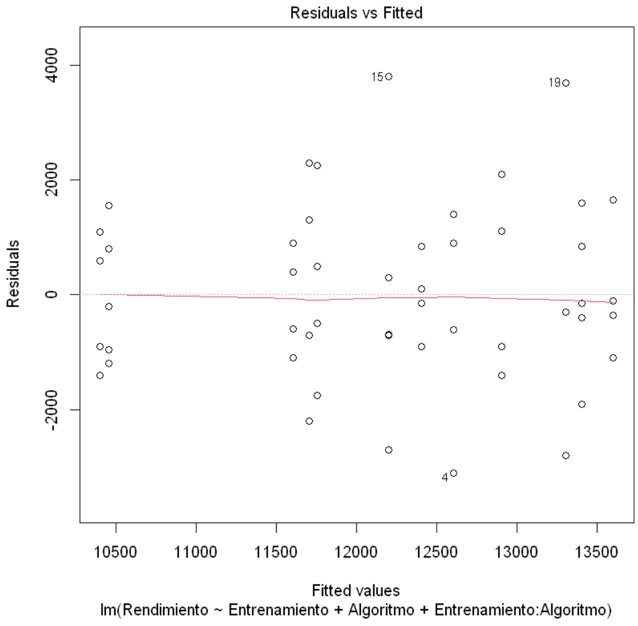
A anova: 4 × 4

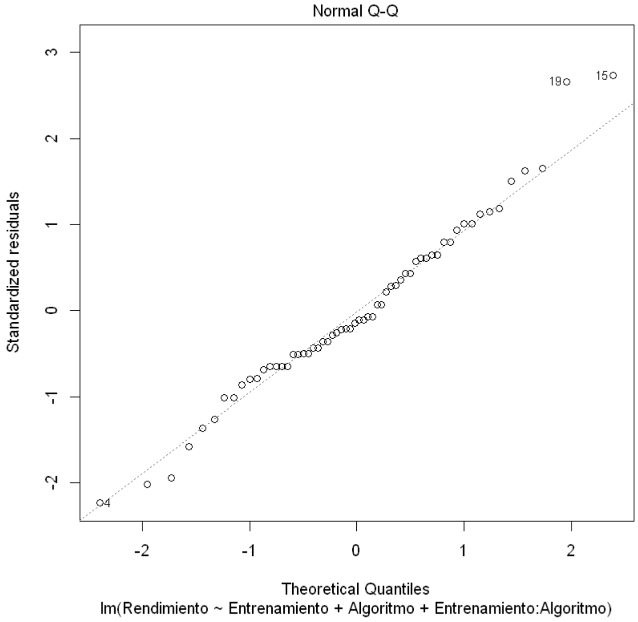
	Sum Sq	Df	F value	Pr(>F)
	<dbl>	<dbl>	<dbl>	<dbl>
Entrenamiento	30621741	3	4.2341389	0.009822338
Algoritmo	28982927	2	6.0113044	0.004679860
Entrenamiento:Algoritmo	2444325	6	0.1689912	0.983866401
Residuals	115713695	48	NA	NA

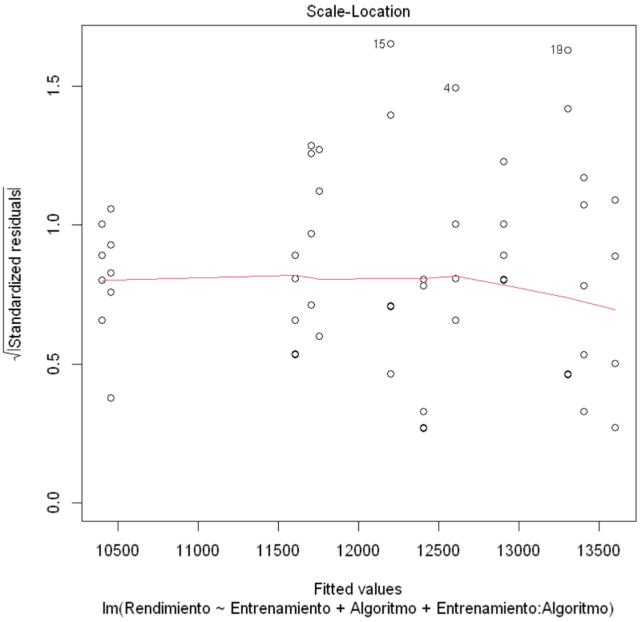



Frequency
0
5
10
15
20
-4000
-2000
0
2000
4000
x


residuals(model)
-3000
-2000
-1000
0
1000
2000
3000
4000
10500
11000
11500
12000
12500
13000
13500
fitted(model)


Residuals vs Fitted
Residuals
-2000
0
2000
4000
15
19
4
10500
11000
11500
12000
12500
13000
13500
Fitted values
lm(Rendimiento ~ Entrenamiento + Algoritmo + Entrenamiento:Algoritmo)





```
NOTE: Results may be misleading due to involvement in interactions
```

```
$lsmeans              $bhat
                      $V







                      $levels

                      $linfct




                      $dffun

                      $dfargs
                      $post.beta




                      $estName
                      $estType
                      $infer
                      $level
                      $adjust
                      $famSize
                      $avgd.over
                      $sigma
                      $methDesc
                      $extras

$contrasts            $bhat
```

.wgt.
<dbl>
20
20
20

$V

	(Intercept)	En
(Intercept)	482140.4	
EntrenamientoMT1000	-482140.4	
EntrenamientoMT5000	-482140.4	
EntrenamientoMT50000	-482140.4	
AlgoritmoAlgoritmo B	-482140.4	
AlgoritmoAlgoritmo C	-482140.4	
EntrenamientoMT1000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT5000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT50000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT1000:AlgoritmoAlgoritmo C	482140.4	
EntrenamientoMT5000:AlgoritmoAlgoritmo C	482140.4	
EntrenamientoMT50000:AlgoritmoAlgoritmo C	482140.4	

$levels

$contrast =
'Algoritmo A - Algoritmo B' · 'Algoritmo A - Algoritmo C' ·

$linfct

(Intercept)	EntrenamientoMT1000	EntrenamientoMT5000
0	0	0
0	0	0
0	0	0

$dffun

```
function (k, dfargs)
dfargs$df
```

$dfargs
$df = 48

$post.beta

A matrix: 1 × 1 of type lgl

NA

$estName 'estimate'

$estType 'pairs'

$infer FALSE · TRUE

$level 0.95

$adjust 'tukey'

$famSize 3

$avgd.over 'Entrenamiento'

$methDesc 'pairwise differences'

$is.new.rg FALSE

$.pairby ''

$orig.grid

A data.frame: 3 × 1

Algoritmo
<fct>
Algoritmo A
Algoritmo B
Algoritmo C

$con.coef

A matrix: 3 × 3 of type dbl

	Algoritmo A	Algoritmo B	Algor
Algoritmo A - Algoritmo B	1	-1	
Algoritmo A - Algoritmo C	1	0	
Algoritmo B - Algoritmo C	0	1	

```
Loading required package: mvtnorm

Loading required package: survival

Loading required package: TH.data

Loading required package: MASS


Attaching package: 'TH.data'


The following object is masked from 'package:MASS':

    geyser


Note: adjust = "tukey" was changed to "sidak"
because "tukey" is only appropriate for one set of pairwise comparisons
```

A summary_emm: 3 × 7

	Algoritmo	lsmean	SE	df	lower.CL	upper.CL	.group
	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<chr>
3	Algoritmo C	11242.45	347.1817	48	10383.55	12101.35	a
2	Algoritmo B	12467.05	347.1817	48	11608.15	13325.95	b
1	Algoritmo A	12878.95	347.1817	48	12020.05	13737.85	b

```
NOTE: Results may be misleading due to involvement in interactions
```

$lsmeans

$bhat

$V

$levels

$linfct

$dffun

$dfargs

$post.beta

$estName

$estType

$infer

$level

$adjust

$famSize

$avgd.over

$sigma

$methDesc

$extras

.wgt.
<dbl>
15
15
15
15

$bhat

12604 · 799.199999999997 · -401.200000000003 · 701.7999

$V

	(Intercept)	En
(Intercept)	482140.4	
EntrenamientoMT1000	-482140.4	
EntrenamientoMT5000	-482140.4	
EntrenamientoMT50000	-482140.4	
AlgoritmoAlgoritmo B	-482140.4	
AlgoritmoAlgoritmo C	-482140.4	
EntrenamientoMT1000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT5000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT50000:AlgoritmoAlgoritmo B	482140.4	
EntrenamientoMT1000:AlgoritmoAlgoritmo C	482140.4	
EntrenamientoMT5000:AlgoritmoAlgoritmo C	482140.4	
EntrenamientoMT50000:AlgoritmoAlgoritmo C	482140.4	

$levels

$contrast =
'MT500 - MT1000' · 'MT500 - MT5000' · 'MT500 - MT5000C

$linfct

(Intercept)	EntrenamientoMT1000	EntrenamientoMT5000
0	-1	0
0	0	-1
0	0	0
0	1	-1
0	1	0
0	0	1

$dffun

```
function (k, dfargs)
dfargs$df
```

$dfargs

$df = 48

$post.beta

A matrix: 1 × 1 of type lgl
NA

$estName

'estimate'

$estType

'pairs'

$infer	FALSE · TRUE
$level	0.95
$adjust	'tukey'
$famSize	4
$avgd.over	'Algoritmo'
$methDesc	'pairwise differences'
$is.new.rg	FALSE
$.pairby	''
$orig.grid	A data.frame: 4 × 1

Entrenamiento
<fct>
MT500
MT1000
MT5000
MT50000

$con.coef

A matrix: 6 × 4 of type dbl

	MT500	MT1000	MT5000	MT50000
MT500 - MT1000	1	-1	0	0
MT500 - MT5000	1	0	-1	0
MT500 - MT50000	1	0	0	-1
MT1000 - MT5000	0	1	-1	0
MT1000 - MT50000	0	1	0	-1
MT5000 - MT50000	0	0	1	-1

```
Note: adjust = "tukey" was changed to "sidak"
because "tukey" is only appropriate for one set of pairwise comparisons
```

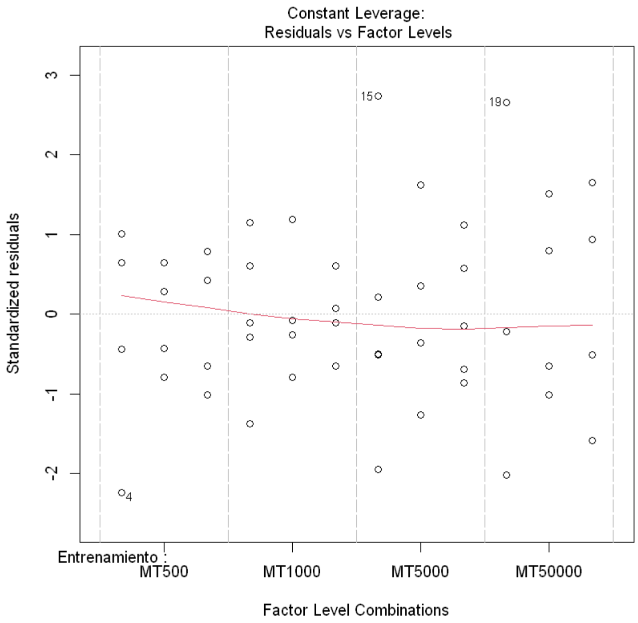
A summary_emm: 4 × 7

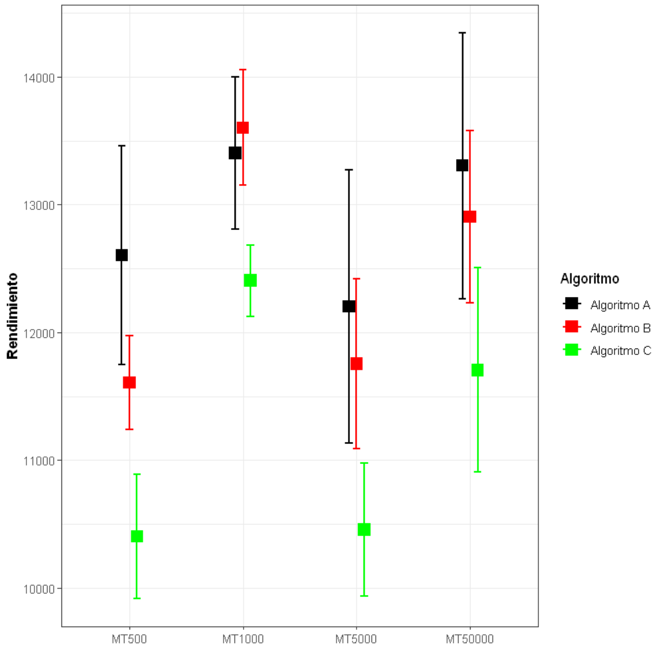
	Entrenamiento	lsmean	SE	df	lower.CL	upper.CL	.group
	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<chr>
3	MT5000	11470.67	400.8908	48	10433.24	12508.09	a
1	MT500	11537.80	400.8908	48	10500.38	12575.22	a
4	MT50000	12638.87	400.8908	48	11601.44	13676.29	ab
2	MT1000	13137.27	400.8908	48	12099.84	14174.69	b

A data.frame: 12 × 11

Entrenamiento	Algoritmo	n	mean	sd	min	Q1	median	Q3	max	se
<fct>	<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
MT500	Algoritmo A	5	12604.0	1918.400	9503	12000	13508	14004	14005	858
MT1000	Algoritmo A	5	13403.2	1330.104	11502	13006	13252	14253	15003	595
MT5000	Algoritmo A	5	12202.8	2386.861	9500	11504	11506	12504	16000	1070
MT50000	Algoritmo A	5	13305.8	2332.843	10506	13005	13008	13008	17002	1040
MT500	Algoritmo B	5	11605.4	822.896	10504	11005	12002	12007	12509	368
MT1000	Algoritmo B	5	13602.8	1010.473	12504	13252	13501	13501	15256	452
MT5000	Algoritmo B	5	11754.0	1488.960	10006	11252	11255	12253	14004	666
MT50000	Algoritmo B	5	12906.0	1514.683	11505	12007	12009	14009	15000	677
MT500	Algoritmo C	5	10404.0	1084.210	9000	9509	11003	11003	11505	485
MT1000	Algoritmo C	5	12405.8	625.963	11508	12254	12506	12508	13253	280
MT5000	Algoritmo C	5	10455.2	1166.849	9255	9500	10257	11255	12009	522
MT50000	Algoritmo C	5	11704.8	1789.237	9509	11000	11001	13009	14005	800

```
Warning message:
"Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
i Please use `linewidth` instead."
```




Rendimiento
14000
13000
12000
11000
10000
MT500
MT1000
MT5000
MT50000
Algoritmo
Algoritmo A
Algoritmo B
Algoritmo C

```
In [ ]:
```